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Enclosed is a draft of the document, "Data Communications Facilities." As mentioned in my letter of November 28, this is a by-product of the development of section IIIB of the working group report on the IMP.

The attached document is incomplete (as were the previous ones) as schedules, topology, traffic, and related items are unknown at this time. The specification of the routing and numbers of leased trunks, for use between the communication switching centers, was avoided; this is due to difficulties encountered in dealing with a broad specification, rather than focusing attention on one or two specific network layouts.

In considering the effects of a requirement for automatic remote loading of programs into the IMP, I suspect we may want to provide some additional communication facilities for control purposes. One dial-up circuit (via existing commercial facilities) with a low-speed data set, per IMP, may suffice. This automatic loading feature should be explored.

Note that the communication specifications do not require the voice coordination circuits be provided. I tend to feel normal telephone or teletypewriter service might be sufficient.

Very truly yours,

A handwritten signature in black ink, appearing to read "Elmer B. Shapiro".

Elmer B. Shapiro
Senior Research Engineer

EBS:pc

11/29/67

Draft Report
For
Data Communication Facilities

I. Introduction

A network of digital computers is to be formed. The network, consisting of XX computers located at 19 sites, is to serve the research needs of ARPA contractors. Many of these computers, called host computers here, use time-sharing techniques and provide services in an on-line interactive manner to human users. These users communicate with the host computers through consoles, such as teletypewriters, or cathode-ray-tube displays and associated keyboards. The computer network will serve to expand the scope of services that can be offered the users of these host machines, permitting rapid, accurate exchanges of programs and data among these computers. The network itself is to be a subject of research and study for such topics as routing doctrines, traffic flows, and queuing.

To facilitate the operation of such a network, a small stored program digital computer, called an interface message processor (IMP), is to be used. Typically, an IMP will be interposed between a host computer and the communication facilities that serve the information transfers to the other network sites. The IMP's, all essentially identical with respect to hardware and programs, serve (1) to organize the transferred information into messages, and blocks, (2) to effect error control and acknowledgement processes, (3) to control

contractor supplying the IMP's.

The communication contractor shall maintain the communication facilities as discussed in Section V, and provide maintenance personnel and spare parts such that repairs to terminals can be initiated, during normal working hours, at the terminal site within two hours after a fault has been called to the attention of the contractor.

III. Functional Requirements

A. Transmission Speeds

Data shall be transferred between the IMP and the communication terminal at a rate of 50 kbps or 2.4 kbps, the speed to be determined by the terminal; a given terminal is intended, however, to always operate at only one speed.

At the 50 kbps transmission speed, the transit delay shall not exceed 30 milliseconds, as measured between the input of the transmitting terminal and the output of the receiving terminal. At the 2.4 kbps transmission speed, this delay shall not exceed XX milliseconds.

B. Full Duplex Operation

Each terminal shall be able to operate in the full duplex mode, so that a terminal can transmit only, receive only, or simultaneously transmit and receive, as determined by the IMP's using the circuit. The information being transmitted and

received by a given terminal can be unrelated and independent.

C. Non-Switched and Circuit-Switched Service

A given terminal is intended to always provide only one type of service -- non-switched or circuit-switched. Full duplex operation should be provided with both services.

With circuit-switched service, it is expected that connections will only be established between terminals of the ARPA network, i.e., the network's community of interest is closed and limited. This limited interest does not preclude connections to intercept, busy, test, or other special purpose terminals commonly employed by the communication facilities.

Except for periods of maintenance or repair all the communication facilities are to be continuously available, 24 hours per day, all days of the year.

For circuit-switched service the connection between the calling terminal and the reached terminal shall be established and ready to serve the IMP's (the reached terminal differs from the call terminal in cases of busy, or abnormal conditions) no later than 15 seconds after the final bit of "dialing" information has been presented by the IMP to the calling terminal.

Likewise an established circuit-switched connection must be released (called and calling terminals, and release circuits available for reuse) no later than 15 seconds after the calling or called terminals have been provided a release signal by their connected IMP's.

Any ARPA circuit-switched terminal should be able to establish a connection with any other non-busy ARPA circuit-switched terminal with same speed capability. In multi-terminal sites, such connections between a pair of circuit-switched terminals should be possible. If circuit concentrators are used, they should appear to be non-blocking switches as viewed by any and all network terminals connected to such concentrators. Thus, it should be possible for all network terminals served by a given concentrator to be simultaneously active.

D. Non-Automatic Operation of Terminals

There is no requirement foreseen for non-automatic operation of the communication terminals. Non-automatic operation includes: (1) the use of a voice channel, provided as part of the terminal, (2) the use of audible or visual signalling devices, (3) the use of manual "dials" for directing the circuit-switches, or (4) the use of manual means for answering circuit-switched calls.

This is not to preclude the incorporation of these features by the contractor if necessary for maintenance, or other reasons. These features, even if provided, need not be used in the normal operation of the network.

E. Automatic Answering and Calling

For circuit-switched service the terminals shall respond to IMP generated "connect," "disconnect," and "digits of called number" signals in effecting automatic placement of calls. The calling terminal shall provide indications to the calling IMP regarding (1) the availability of the terminal to initiate a call, (2) readiness to accept called number digits, (3) the disposition of the call (e.g., circuit has been established, called terminal busy, call intercepted, etc.), and (4) the disconnection of a circuit due to abandonment of the call by the called terminal.

Called terminals should indicate to the IMP (1) an unanswered call is awaiting; this indication to disappear when an unanswered call has been abandoned, (2) an answered call has been abandoned, (3) the terminal is available for use after having been released from serving a call. The IMP should be able to indicate to the called terminal (1) an

answer condition, and (2) an answered call is to be disconnected, regardless of the state of the calling terminal.

Automatic line hunting should be used where a site is served by several circuit-switched terminals. It should be possible for the line hunting operation to encompass all of the circuit-switched terminals at a site.

F. Data Sensitivity and Error Control

The average error rate for each established point-to-point communication circuit, whether on a non-switched or circuit-switched basis, shall not exceed XX received bits in error for each 10^6 received bits. This rate shall apply to 2.4 kbps and 50 kbps circuits, and shall apply independently to each direction of transmission of the full duplex circuits.

This average error rate is to be independent of the nature of the information presented to the transmitting terminal, (e.g., even if all 0's and 1's are presented to that terminal).

IV. Estimated Traffic

Non-switched and circuit-switched

On 50 kbps and 2.4 kbps circuits

Message origination rates

Message holding times

Circuit dialing rates

Dialed up circuit holding times

Growth

V. Maintenance and Operation

The contractor shall provide for the maintenance of (1) all contractor supplied terminal equipments, and (2) all communication facilities, both transmission and switching, that serve to interconnect these terminals.

APPENDIX A

Terminal Inventory and Delivery Schedule

ARPA Contractor	Name	Abbrev	Exact Site of Terminals		No. of Terminals*	Delivery Date
			50 kbps	2.4 kbps		
Dartmouth College	Hanover, N. H.				1S	
	DART				3S	
	MAC				3S	
	BBN				2S	
	HARV				2S, 1N(UI)	
	LL					
	BTL					
	ARPA					
	CMU					
	UM					
	UI					
	WU					
Stanford Research Institute	333 Ravenswood Ave, Menlo Park Calif, Bldg 30, Rm K2079				2S, 1N(LL)	
	SRI				2S, 1N(UCB)	12/23/68
	UCB				2S, 1N(SRI)	12/23/68
	SU					
	UTAH					
	UCSB					
	UCLA					
	SDC					
	RAND					

*The suffix S indicates a circuit-switched circuit. The suffix N indicates a non-switched circuit, while the () contain the identity of the other terminal of that circuit.